Use of Multivariate Analysis in a State Water Quality Monitoring Program for Linking Stressors to Biological Impairments

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Robert J. Miltner

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Fact or Opinion?

You can never have too many wooly buggers

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Stressor Identification

- Clean Water Act Section 303(d)
  - A TMDL is a pollution budget for or more pollutant sources
  - Recent Ohio Supreme Court ruled that TMDLs must go through formal rulemaking
- Need to better document causal assessment
  - Systematic approach to analysis
    - Riva-Murray et al. (2002) Northeastern Naturalist 9(2):127-162
    - Morris et al. (2006) Arch. Environ. Contam. Toxicol. 50:325–334
    - Norton et al. (2015) Ecological Causal Assessment (Book)
    - US EPA CADDIS website

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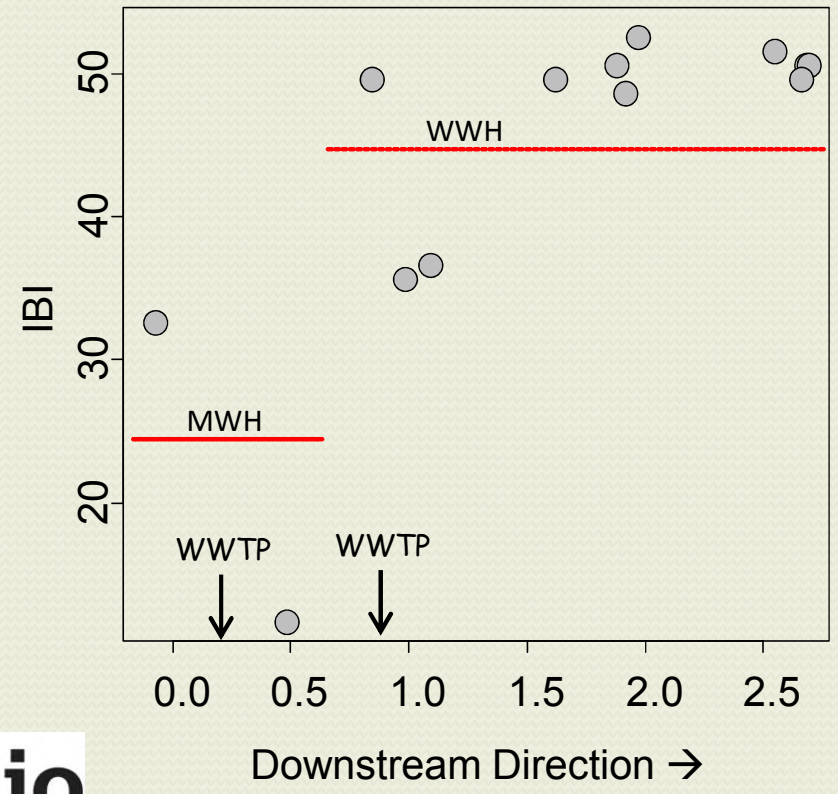
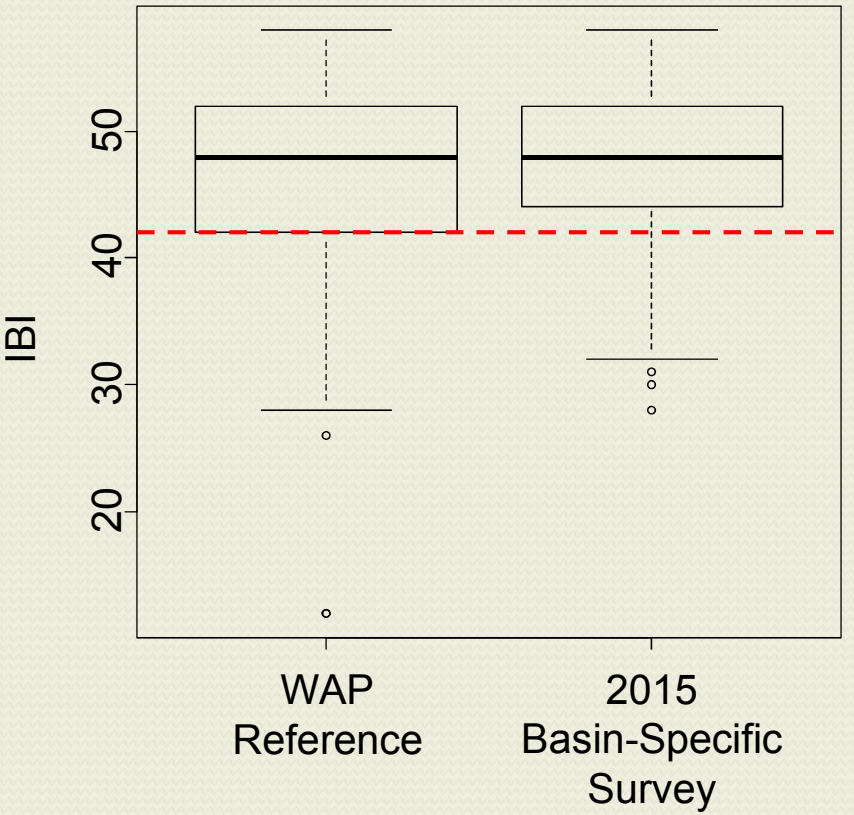
Assessments are More Complex

- Historic focus on point sources
  - free chlorine
  - ammonia
  - BOD
  - effluent toxicity
  - monthly operating reports



- Increased focus on diffuse sources
  - multiple stressors
  - high degree of colinearity
  - restoration target ambiguous
  - WQ standards lacking (sediment)
  - limits of biotic index calibration



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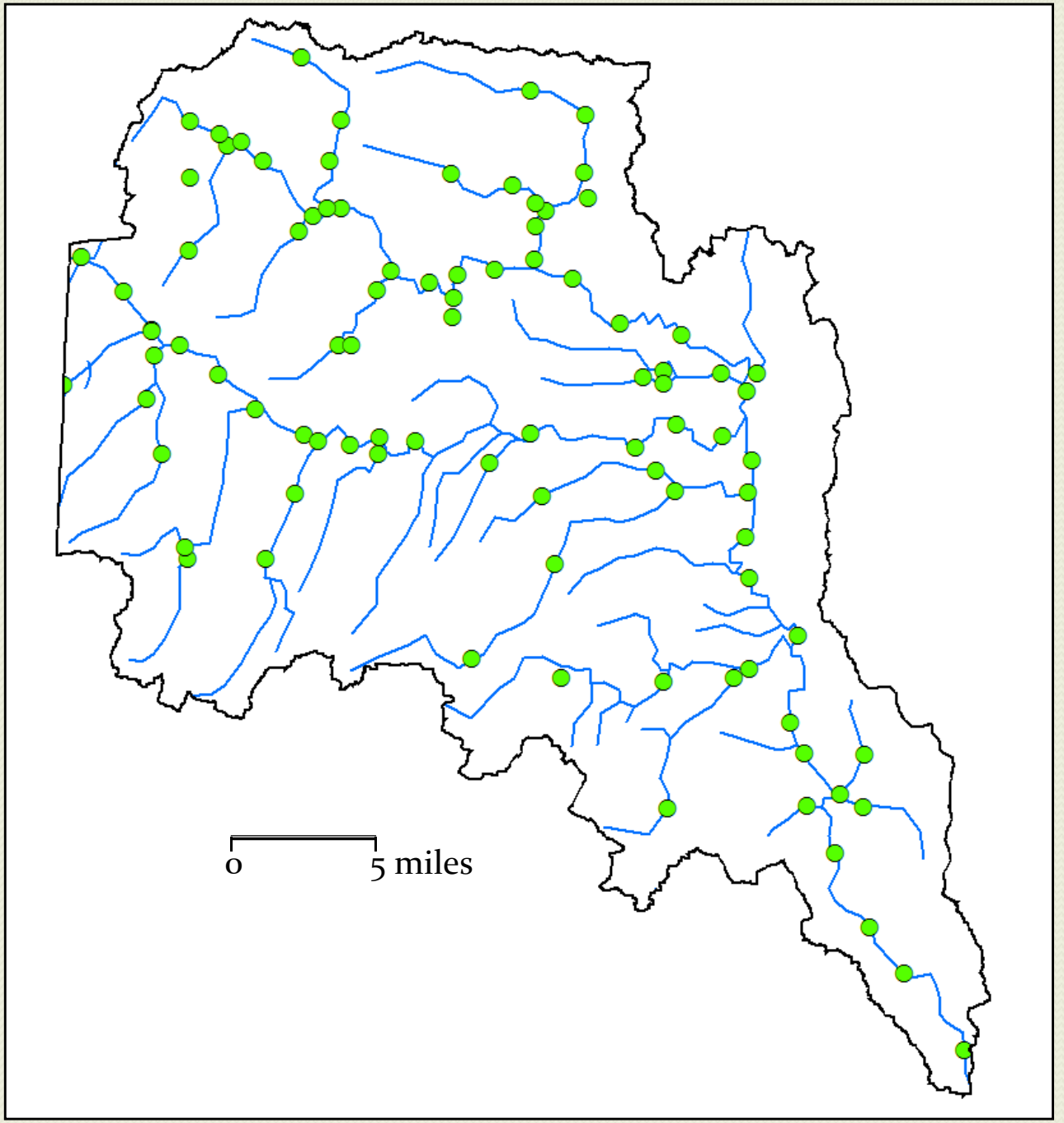
Basin Surveys

300 ~ 700 square miles

60 - 90 sampling locations

geometric progression

targeted sampling



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Outline of Approach

- R used for analyses
- Survey-specific methods
  - ordination of biological data
    - hierarchical clustering - visually identify similar groups
    - nonmetric multidimensional scaling
  - overlay environmental variables on ordination
    - identify candidate stressors, visualize colinearity
  - examine influence of stressors within and across groups
    - boxplots of stressors by group, additive models
    - random forest model
- Comparison to regional models

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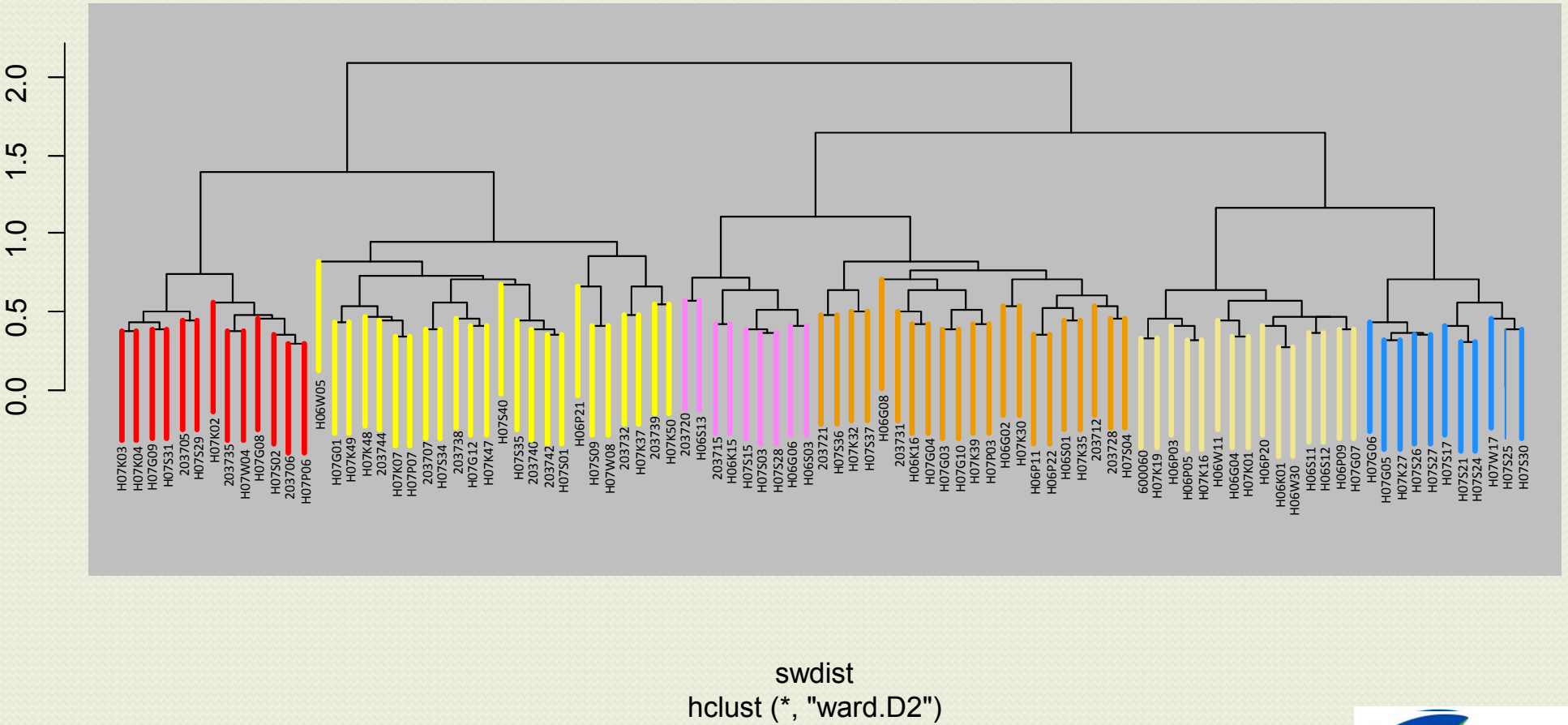
Hierarchical Clustering

Identify groupings of sites based on composition of biological assemblages

- convert biological assemblage counts or presence/absence to distance matrix
- **vegan** package for distance matrix; **hclust** for clustering



swdist
hclust (*, "ward.D2")

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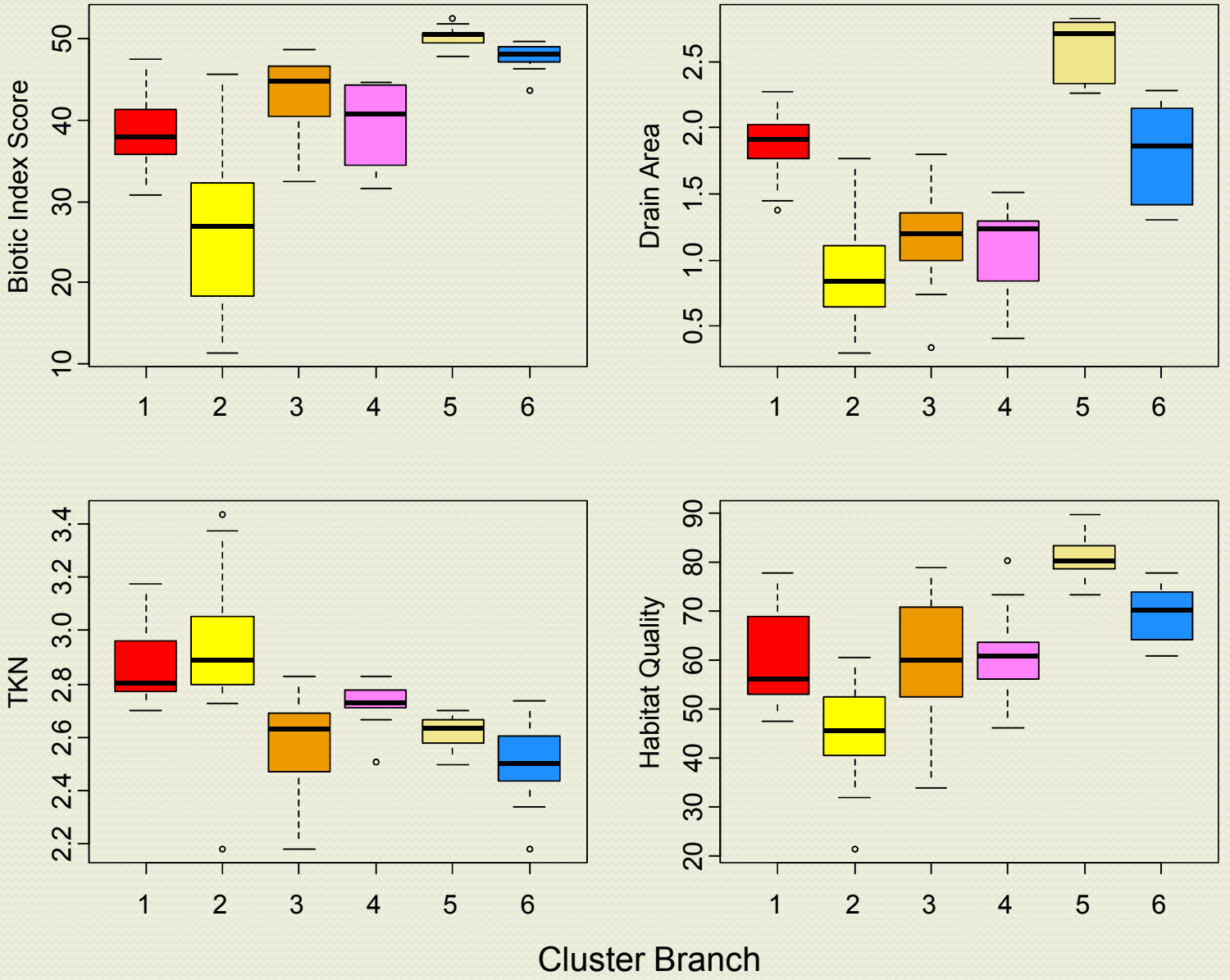
Are Groups Environmentally Meaningful?



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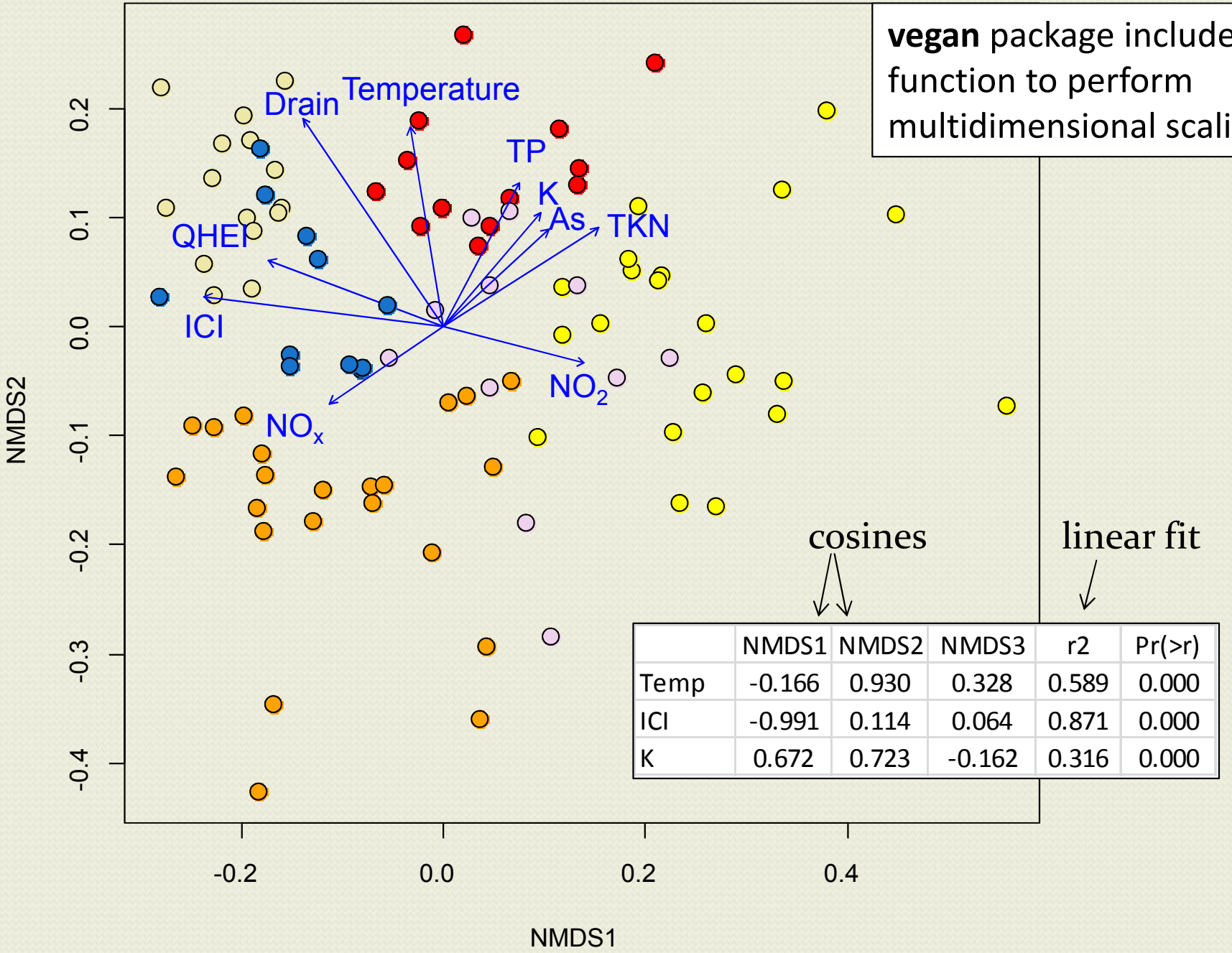
Overlay Environmental Variables on Ordination



vegan package includes function to perform multidimensional scaling

cosines

linear fit

	NMDS1	NMDS2	NMDS3	r2	Pr(>r)
Temp	-0.166	0.930	0.328	0.589	0.000
ICI	-0.991	0.114	0.064	0.871	0.000
K	0.672	0.723	-0.162	0.316	0.000

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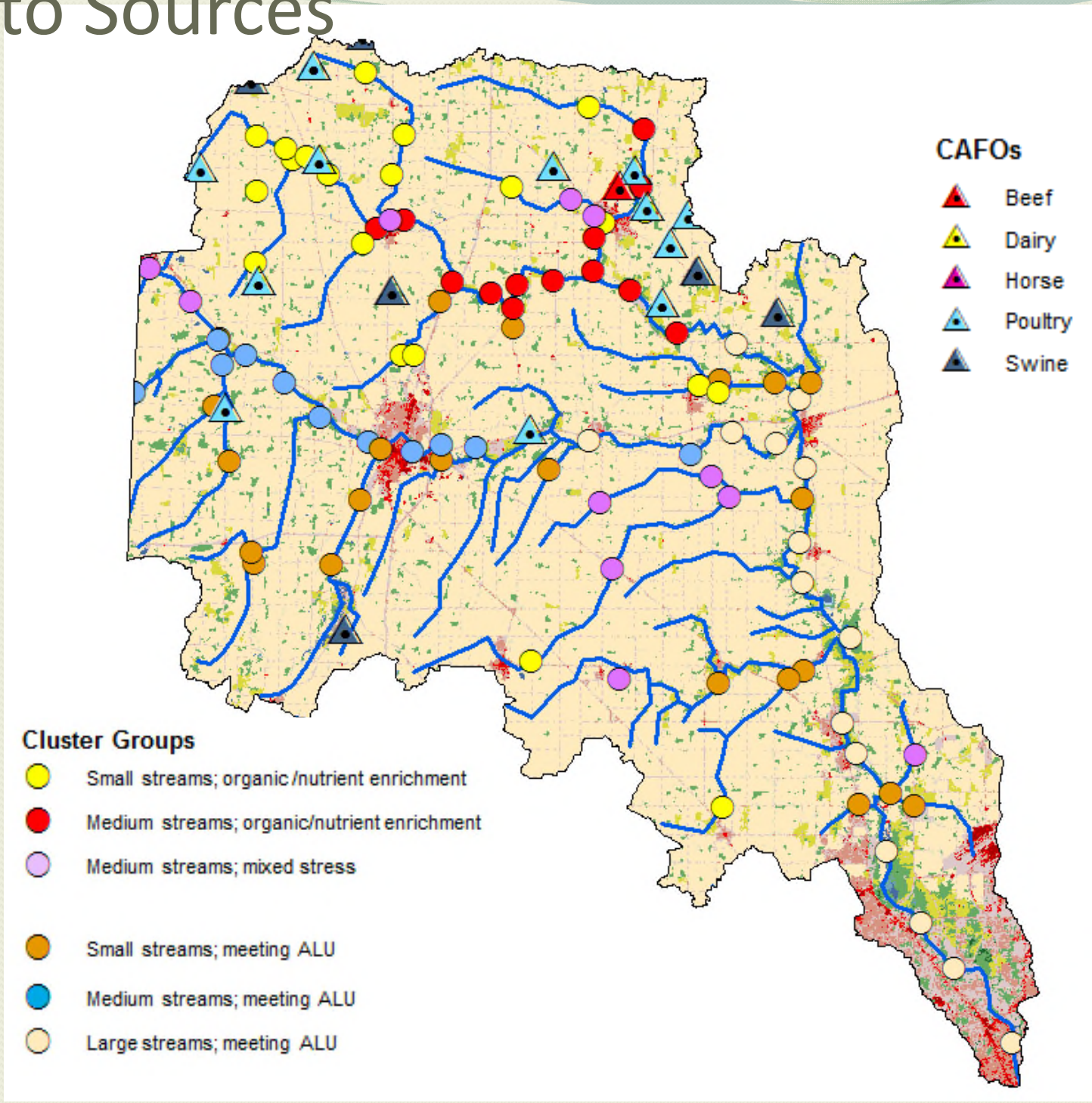
Proximity to Sources



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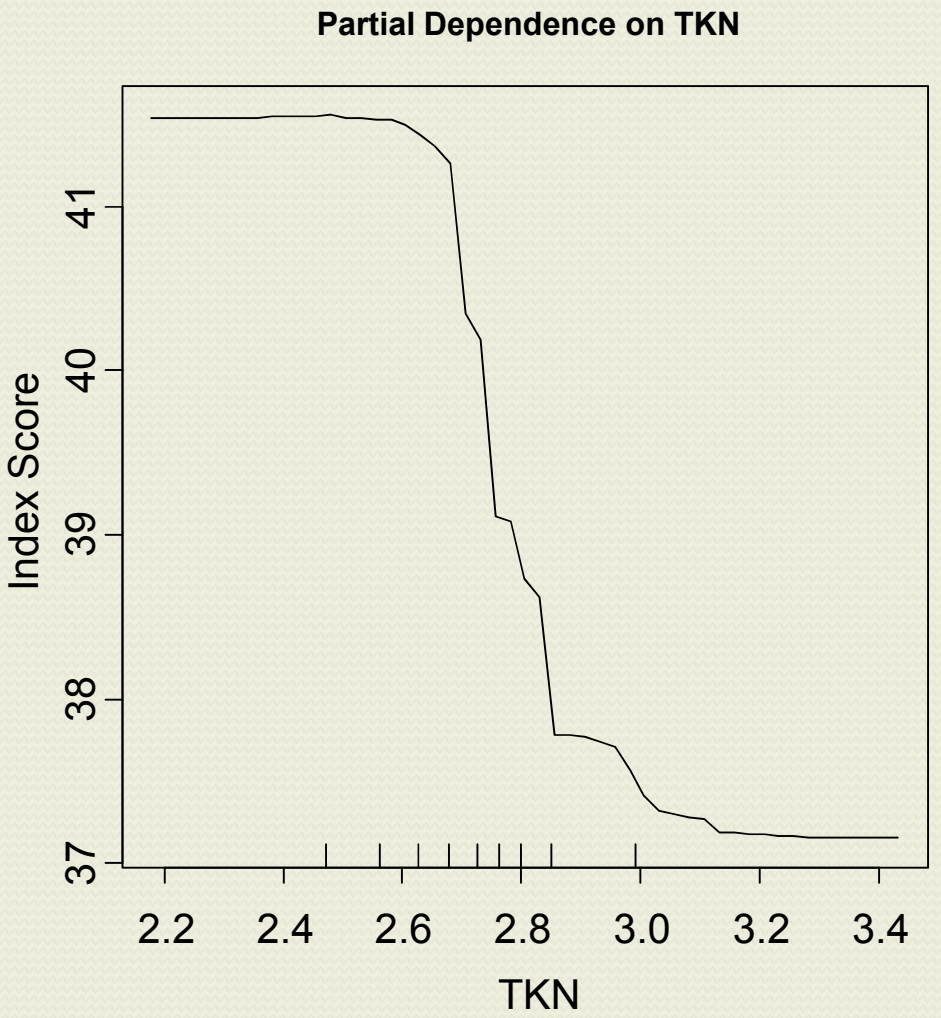
Influence of Stressors - Random Forest Model



Packages:
randomForest
party

var	%IncMSE	IncNodePurity
tkn	20.17087646	1497.93609
da	15.28934007	1019.61436
qhei	14.31103493	1433.53018
no2	8.70120823	841.78265

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Regional Models

Interpret observed/expect

Deviation from reference condition

- e.g., RIVPACS - define groups based on biological assemblages; find environmental variables that best discriminate those groups
- NRSA uses a RIVPACS-type model for o/e

Prediction based on regional data

- Logistic regression

  e.g., model predicting EPT|drainage area

  ECBP of Ohio

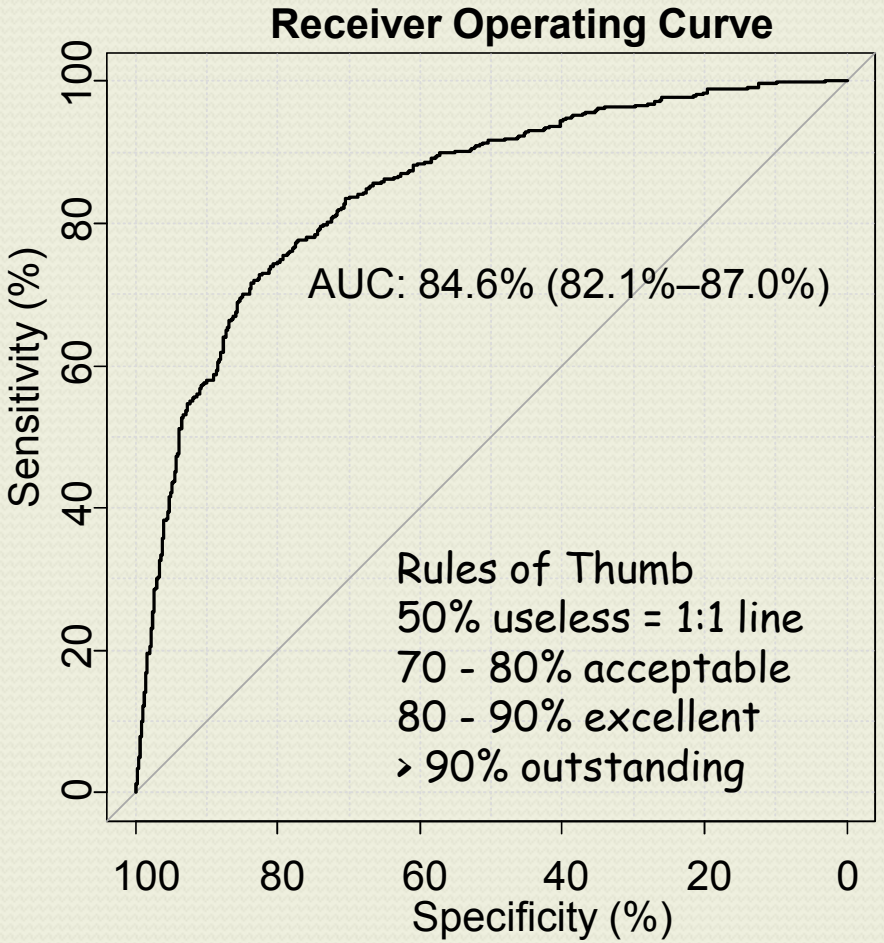
  y = alk + chloride + so4 + D.O. + TKN + QHEI

  evaluation and diagnostics

  ROC curve →

  Hosmer-Lemeshow test

  chi square = 6.697, df= 8, p=0.570



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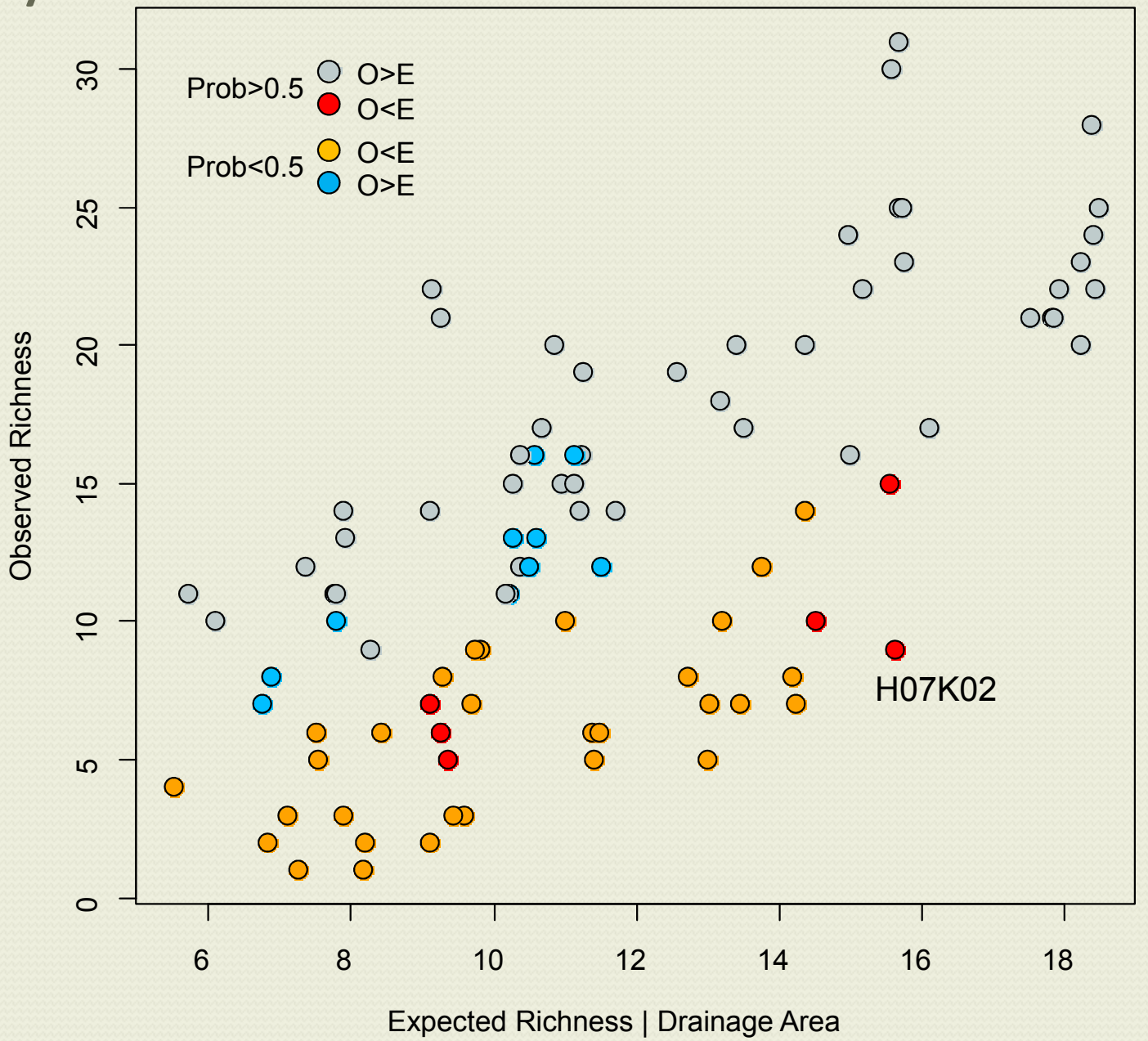
Regional Logistic Regression Model Applied to Specific Survey



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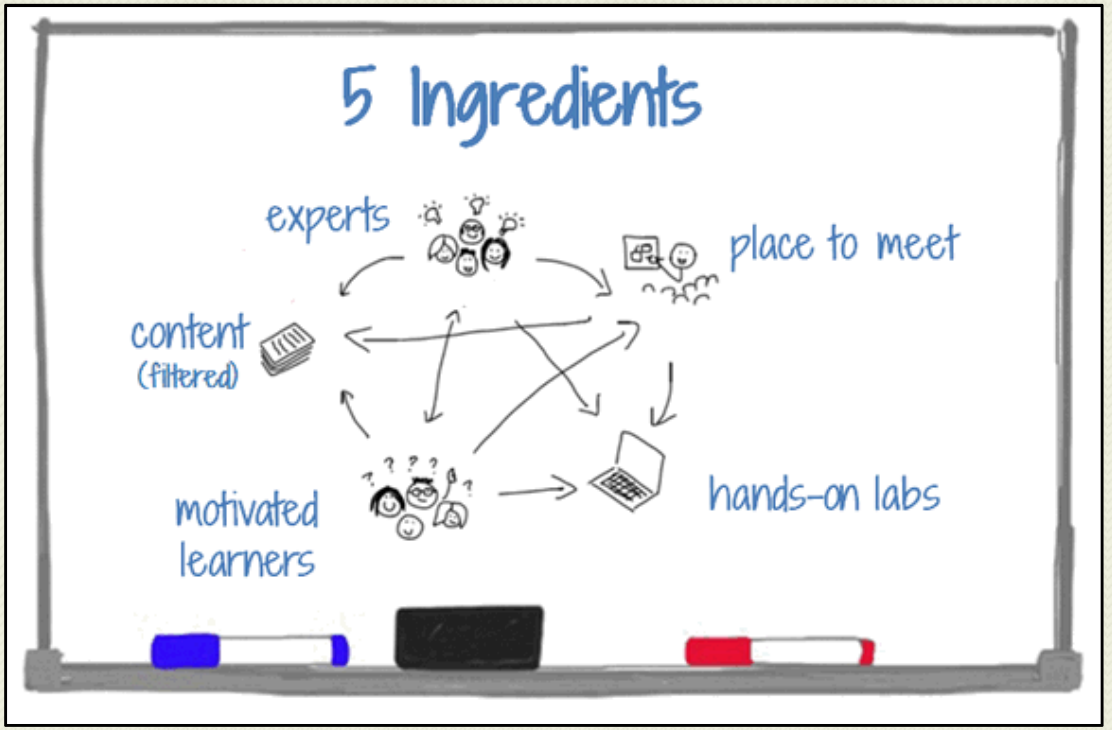
Getting Started

- CADDIS provides walk-throughs of causal assessments; provides introduction to data analysis
- R software
  - package documentation and vignettes
  - excellent on-line help
- **START A LEARNING CIRCLE!**

senior managers - you owe it to your staff

staff - don't ask, just do

middle managers - congratulate your staff on showing initiative



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Parting Thoughts - The Moral of Wooly Bugger

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